Optical depth and altitude of dust aerosols from AIRS and IASI

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Why we are interested in dust aerosols?

Dust aerosols

- affect the earth's radiative budget with participation in the direct, indirect and semi-direct effects, in both solar and terrestrial spectra,
- influence the hydrological cycle by acting as cloud condensation and ice nuclei,
- modify the oxidizing capacity of the atmosphere and thus the concentration of some tropospheric trace gases,
- participate in the fertilization with nutrients of the ocean,
- degrade the restitution of atmospheric and surface parameters from satellite instruments and
- deteriorate the air quality.

Remote sensing of aerosols in the IR

- Remote sensing in the visible domain has been widely used to obtain better characterization of aerosols and their effect on solar radiation.
- On the opposite, remote sensing of aerosols in the infrared (IR) domain still remains marginal, although it can not be omitted.

Advantages of infrared remote sensing:

- retrieval of **aerosols mean altitude** and **coarse mode effective radius** in addition to optical depth at 10 μm,
- possibility of observation during **night and day**, over **sea and land (and above desert)**.

Drawbacks: the influence of atmospheric state and above land of surface properties (temperature and emissivity).

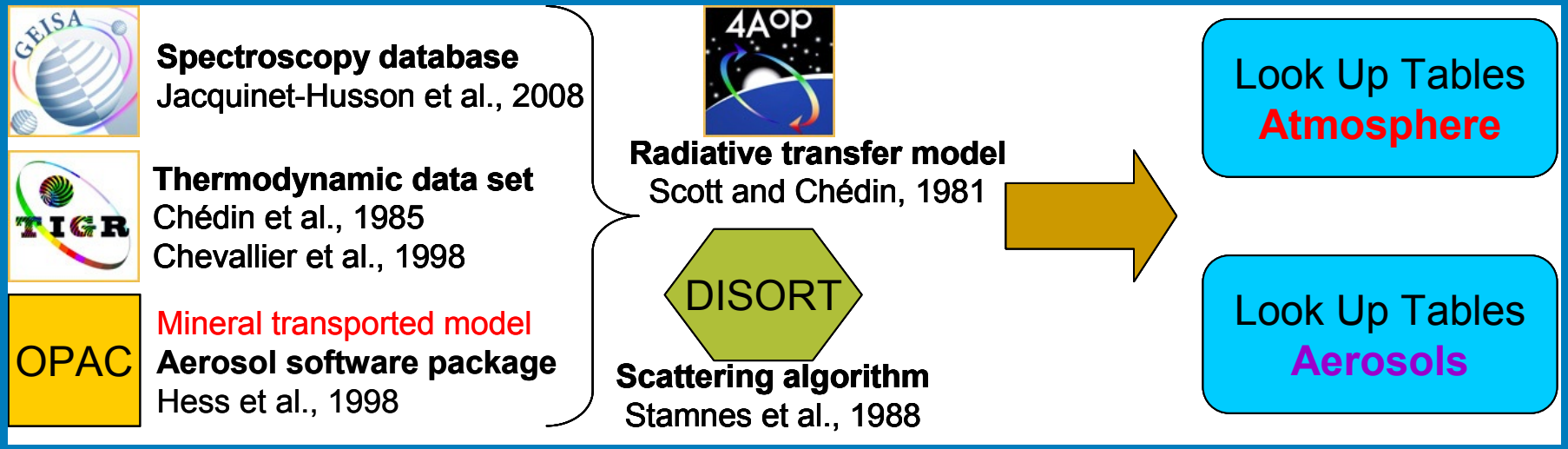
Characteristics of AIRS and IASI

	AIRS	IASI
Launch	May 2002	October 2006
Satellite	Aqua	MetOp-A
Local time (night/ day)	1:30/13:30	21:30/9:30
Instrument	Grating spectrometer	Fourier transform spectrometer
Spectral range	650-2665 cm^{-1} / 3.7-15.4 μm (non continuous)	645-2760 cm^{-1}/ 3.62-15.5 μm
Spectral resolution	0.5-2 cm^{-1}	0.5 cm^{-1} (apodized)
Spatial resolution at nadir	13.5 km	12 km
Channels	2378	8461
Full swath width	2300 km	2200 km

IASI will provide observations for more than 15 years on board of MetOp-A, B, C, while CrIS has been launched on 28 October and it will continue AIRS work.

Aerosols inversion method in the IR

I. Construction of Brightness Temperature Look Up Tables



II. Application of cloud mask.

III. Retrieving atmospheric situation by using the LUTs for Atmosphere.

IV. Retrieving aerosols properties (optical depth, mean altitude and coarse mode effective radius) by using the LUTs for Aerosols.

$$D_{spot}(AOD, alt) = \left[\alpha \sum_{j=1,8} \frac{(TB^{j}_{calc} - TB^{j}_{obs})^2}{\sigma^2_j} + \beta \sum_{k=1,5} \frac{(\Delta TB^{k}_{calc} - \Delta TB^{k}_{obs})^2}{\sigma^2_k} \right]$$

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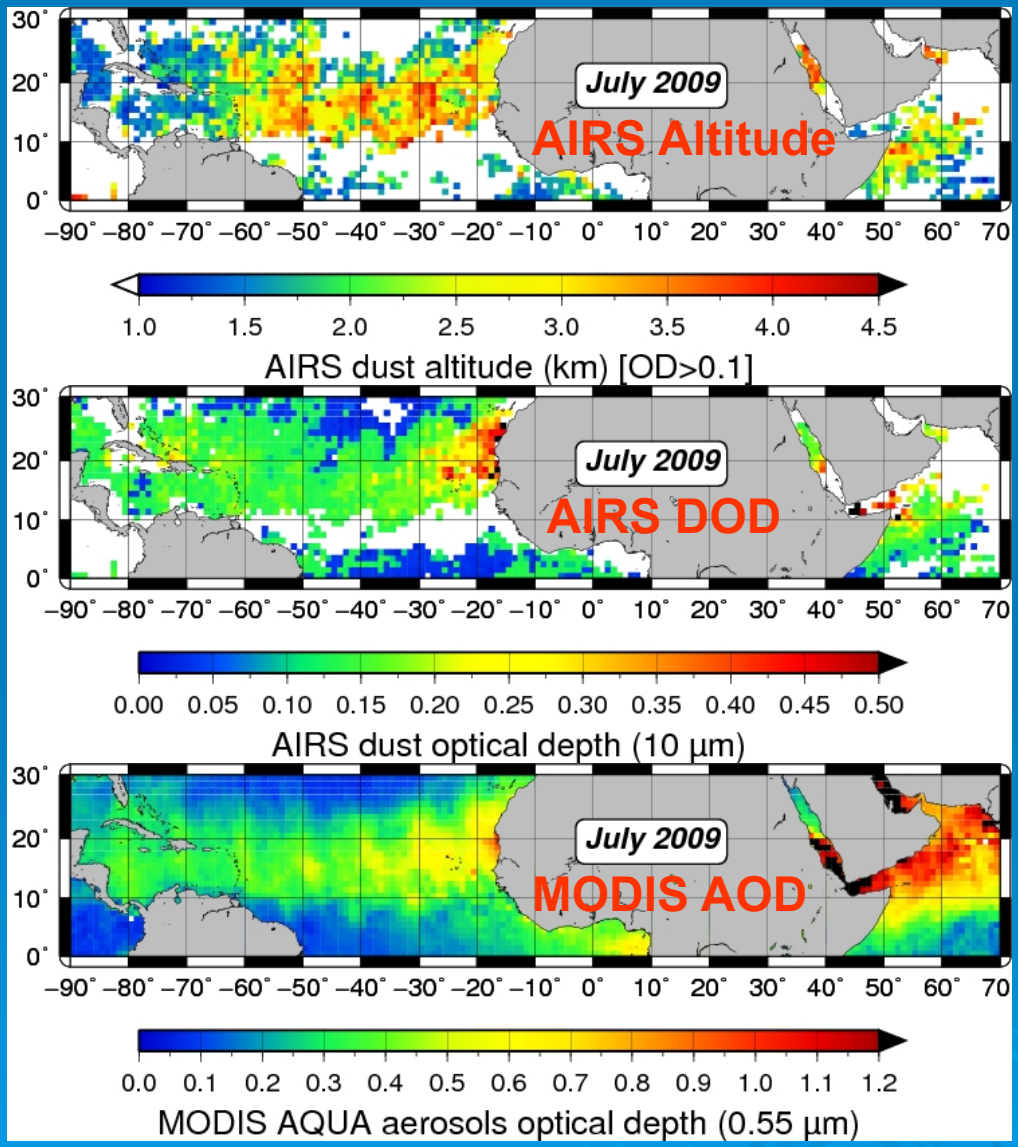
Aerosols products from IR

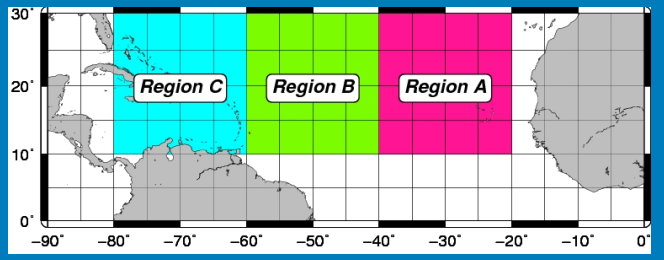


Mean altitude and **optical depth at 10 µm** of dust aerosols.

More than **8.5 years** of AIRS observations with space-time resolution of **1 degree – 1 month**.

Peyridieu et al., ACP, 2010

Comparison of the optical depth with MODIS

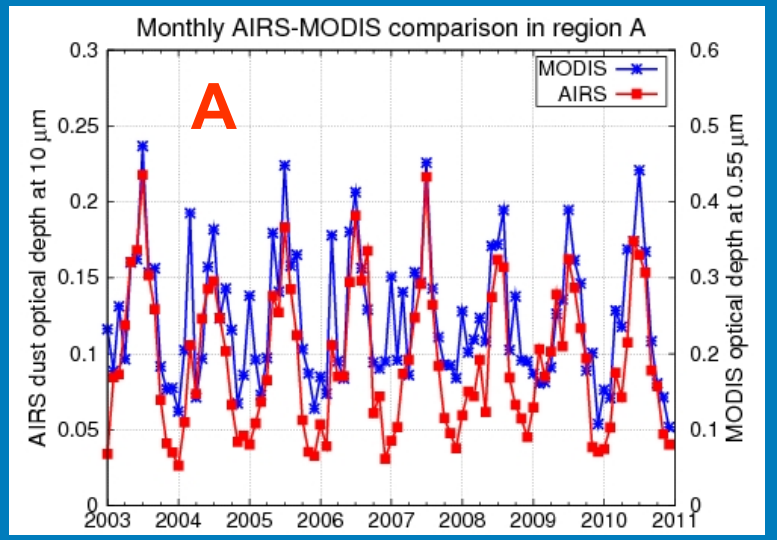


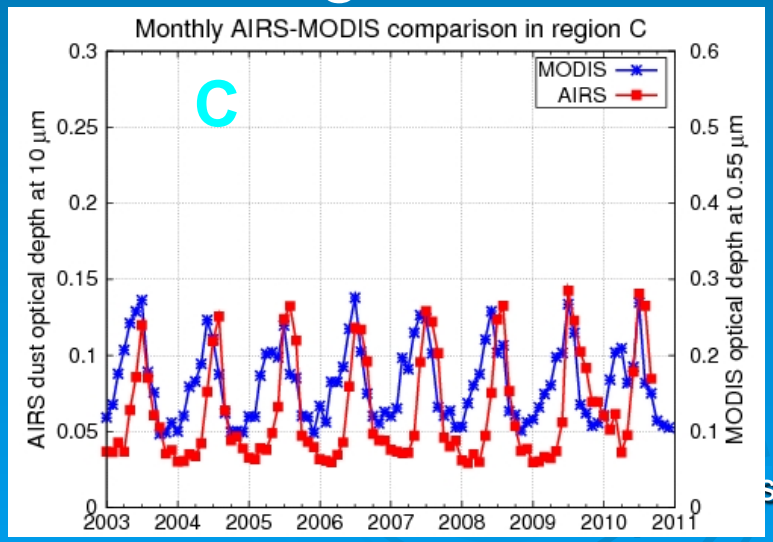
Good temporal correlation with coefficient (ρ)

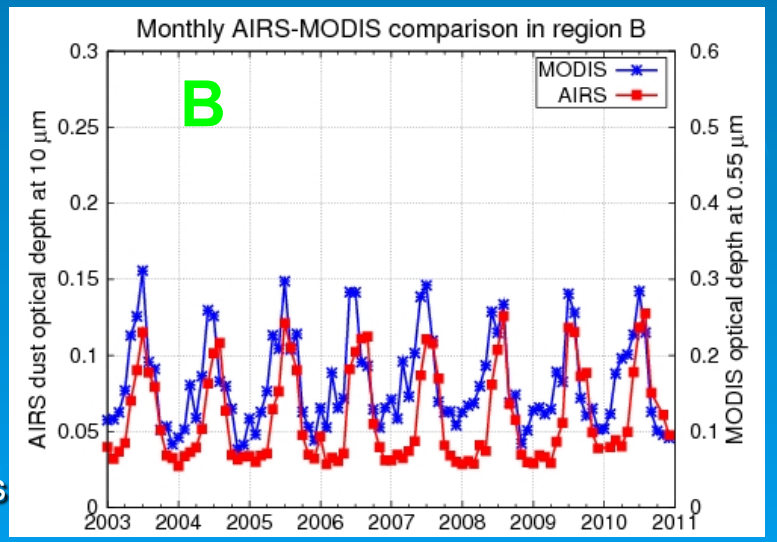
A: 0.83, B: 0.79, C: 0.56

Late arrival of coarse mode dust aerosols in region C.

Peyridieu et al., ACP, 2010







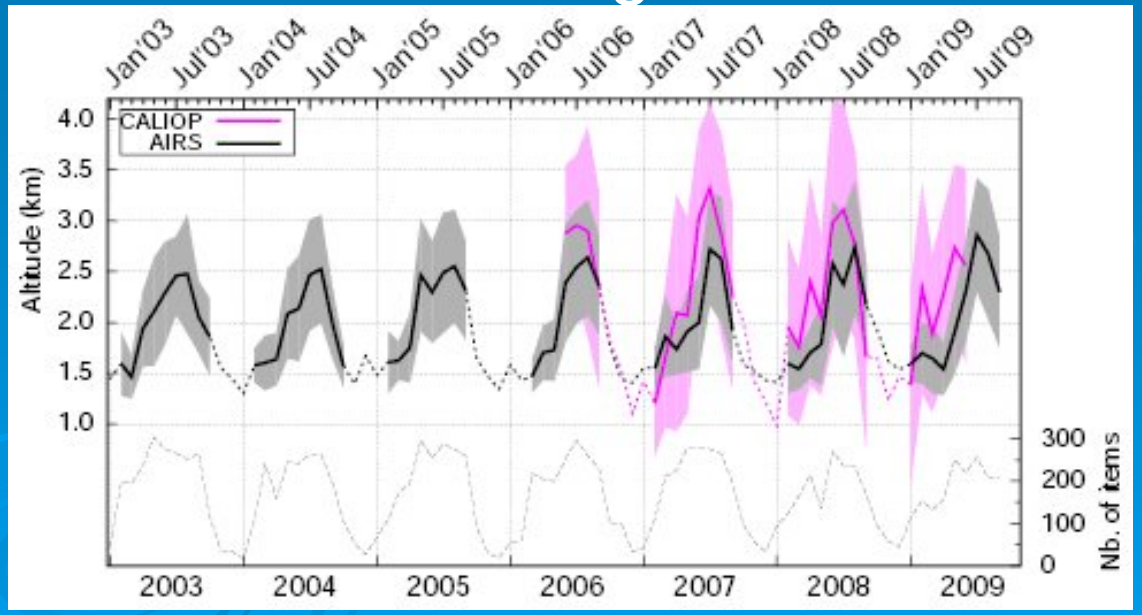
Comparison of the mean altitude with CALIPSO

There is a good temporal correlation for the region near Africa.

<AIRS-CALIOP> ≈ - 470 m

However, there are some problems (inversed north/ south gradient), which are under investigation.

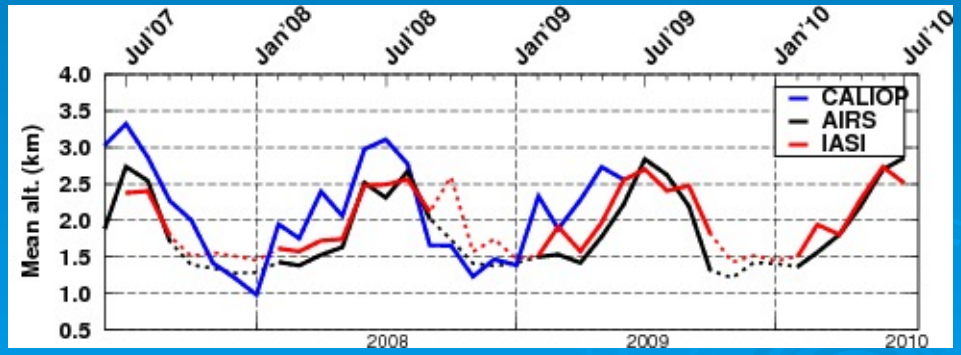
Peyridieu et al., ACP, 2010

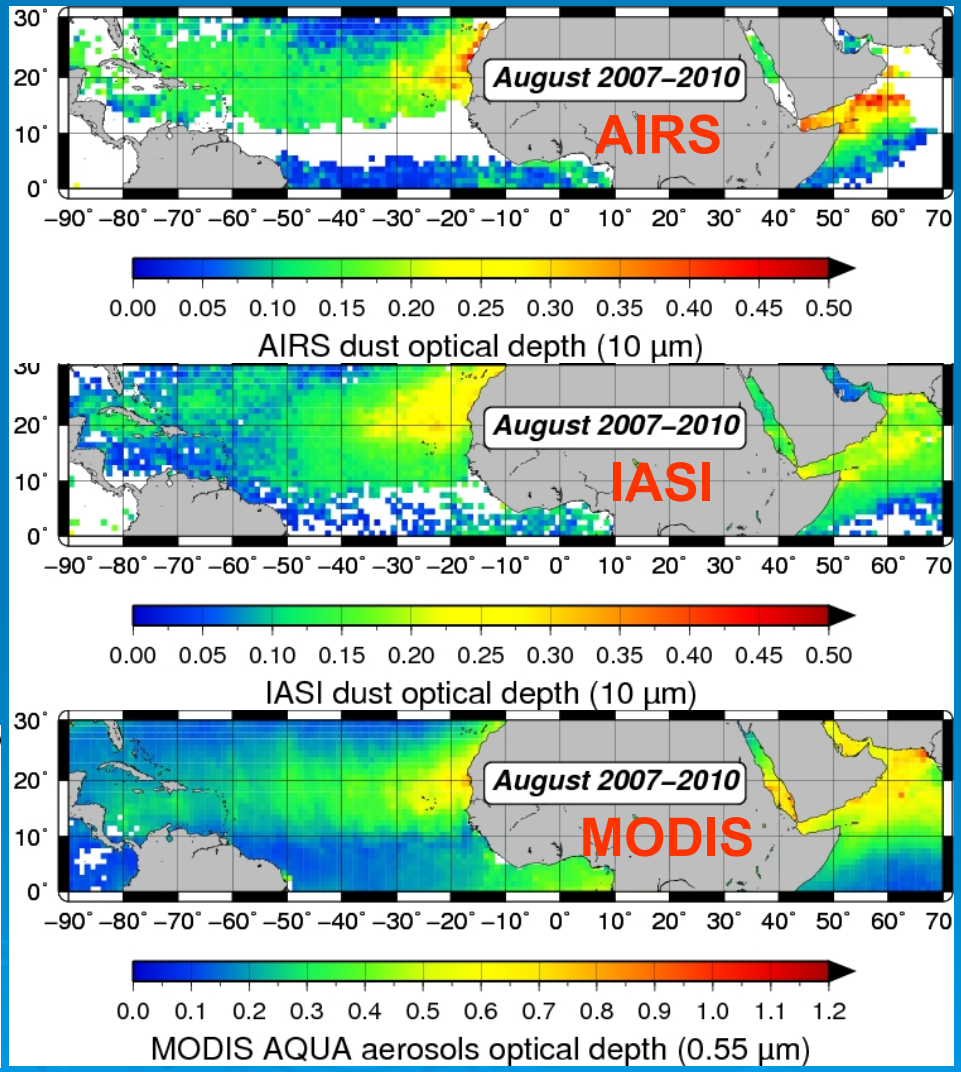


Dust characteristics from IASI

More than 4 years of IASI dust optical depth and mean altitude with space-time resolution of 1 degree – 1 month.

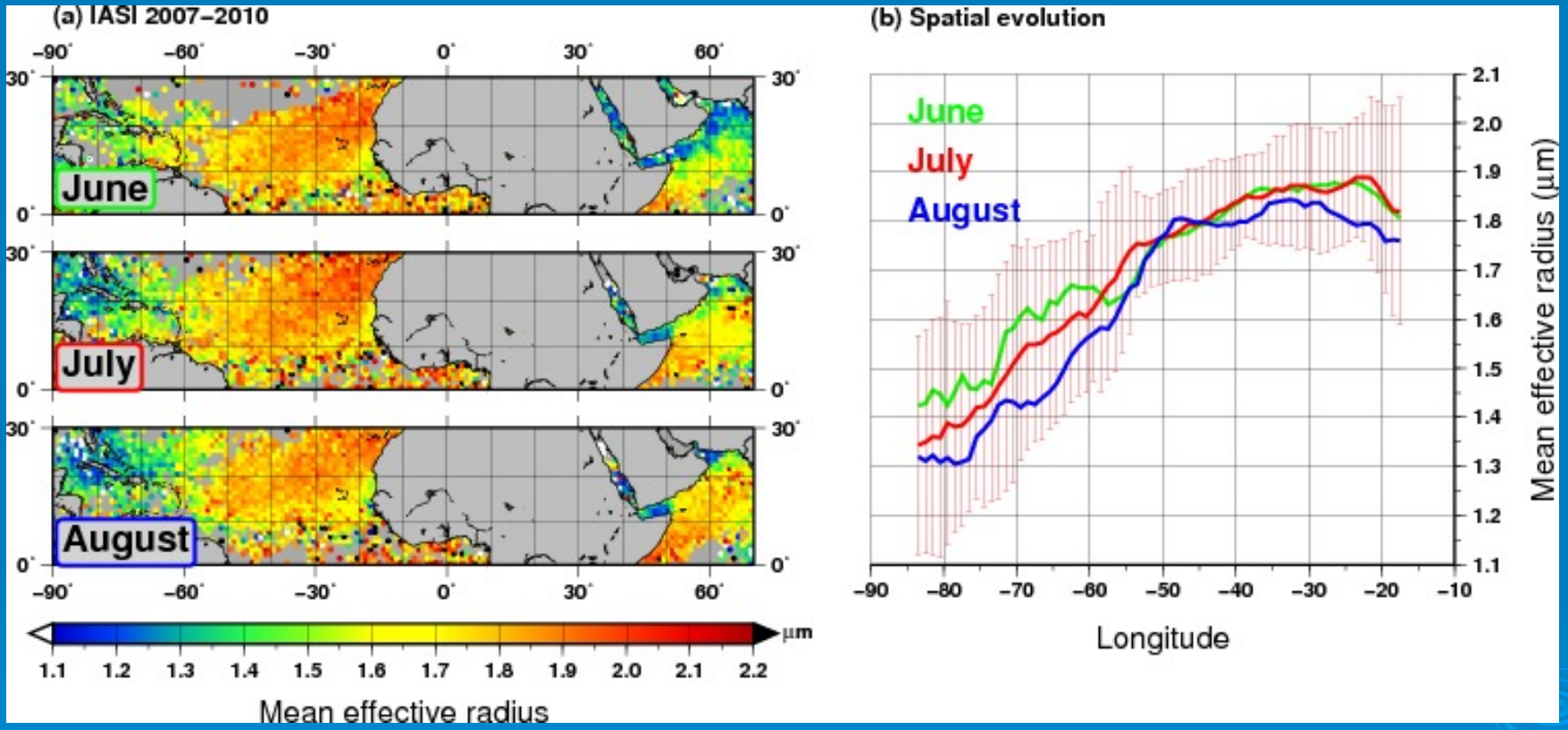
Peyridieu et al., in preparation





AIRS: Pierangelo et al., GRL, 2005

Coarse mode effective radius



First results show decrease of effective radius with transport towards America.

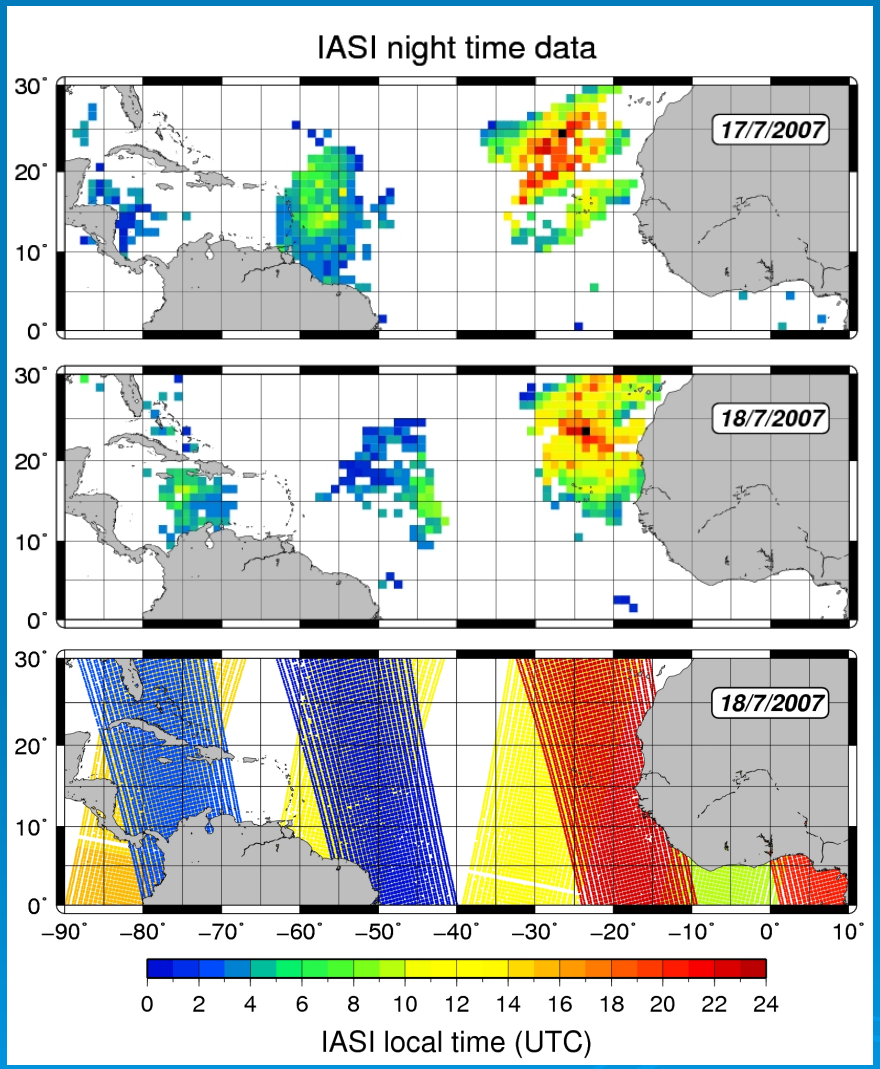
Validation needed (with AERONET ?)

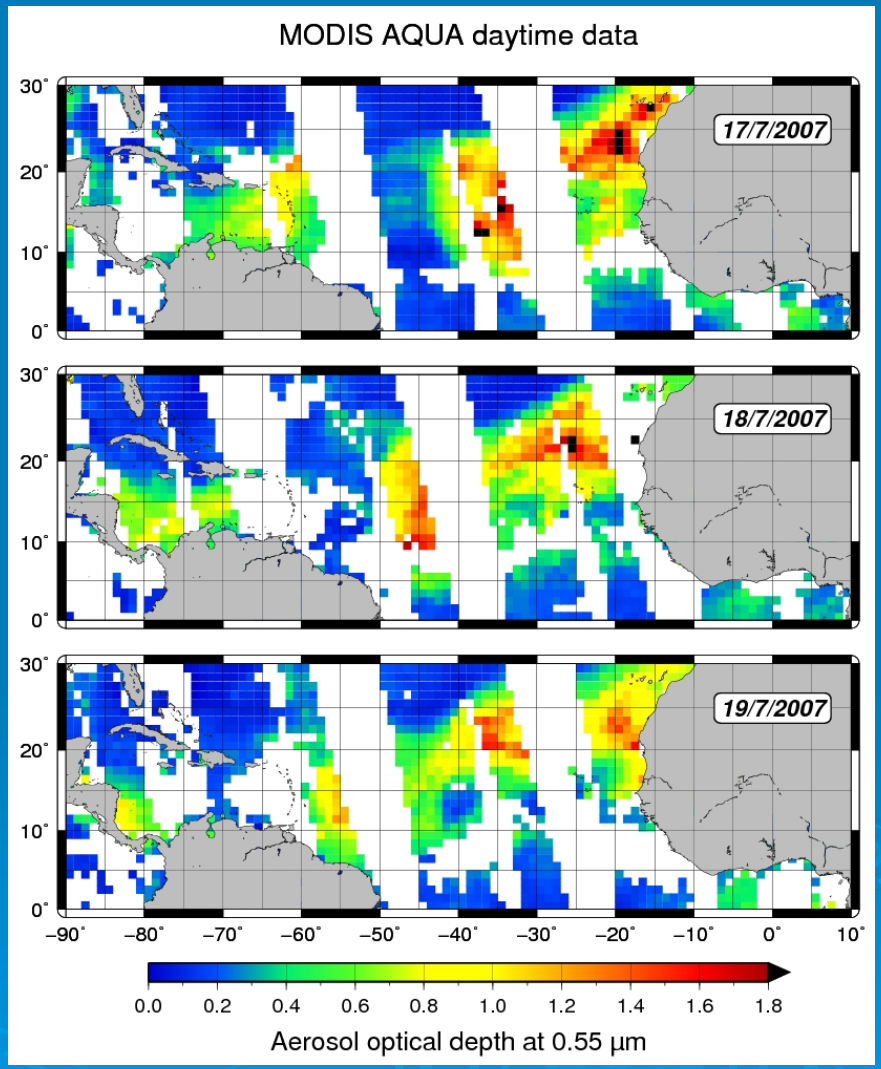
Peyridieu et al., in preparation

Towards a better resolution: 1 day-1 spot

- Aerosols present strong variability with average residence time of roughly one week in the lower troposphere, so the best possible resolution (spatial and temporal) is necessary for their optimal observation and use (study of their implication in the atmospheric processes).
- Use of daily data for assimilation in numerical models and improvement of their performances.
- AIRS or IASI provide aerosol altitude with good spatial coverage on a daily basis when CALIPSO multiannual data must be used.

Daily optical depth from IASI





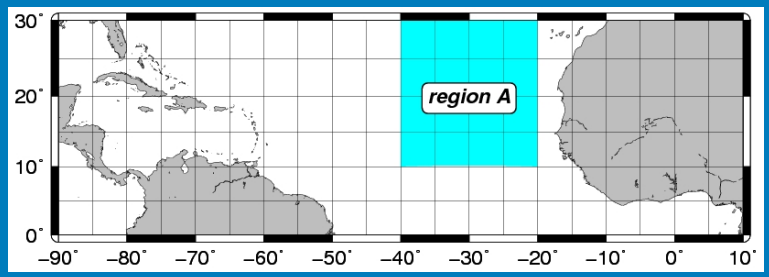
Good spatial correlation between IASI and MODIS

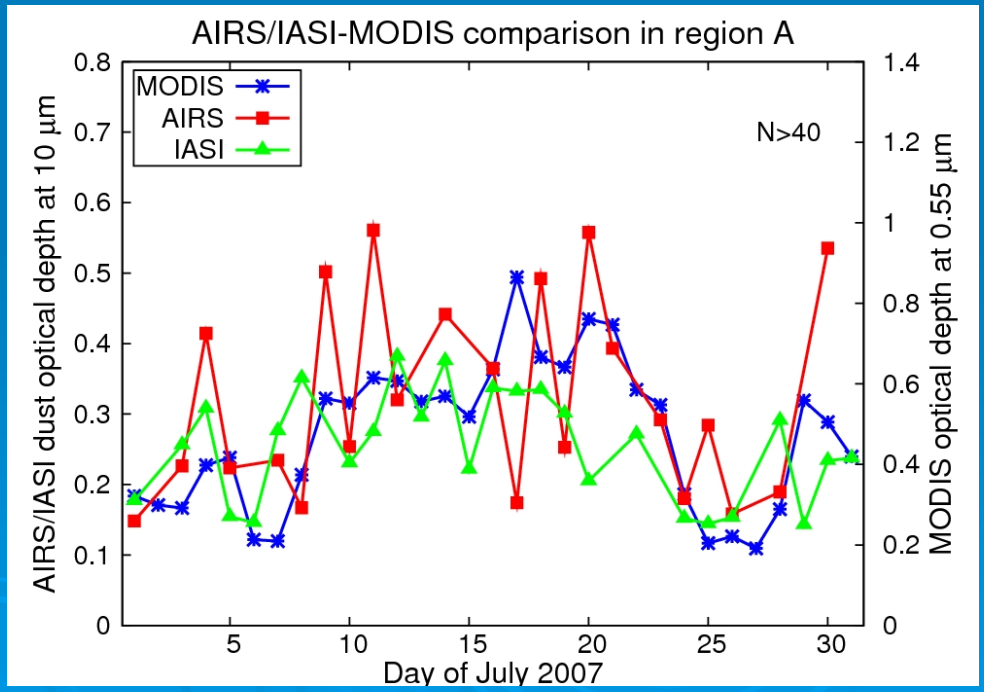
AIRS and IASI daily optical depth comparison with MODIS

Preliminary results (still too noisy) depict relatively good temporal correlation with coefficients:

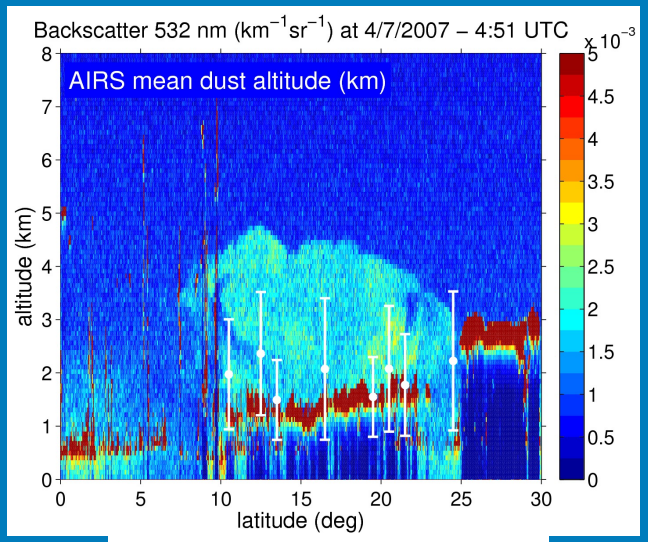
- AIRS – MODIS: ρ=0.51
- IASI – MODIS: ρ=0.48

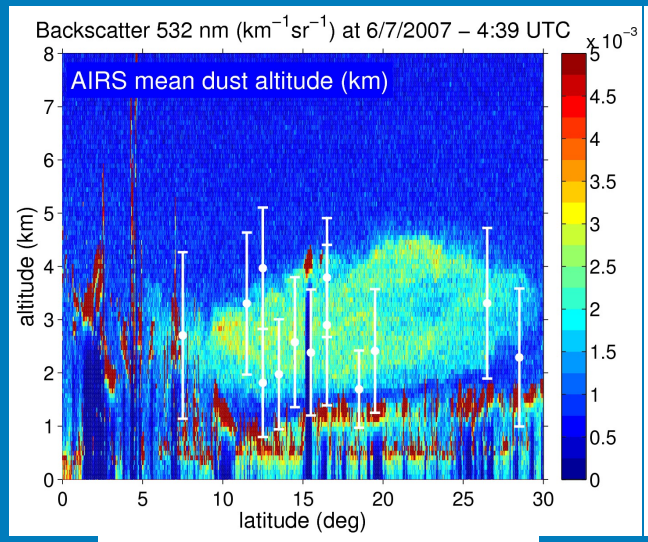
While the correlations of IASI and AIRS with MODIS are similar, the daily variation of IASI is less noisy.

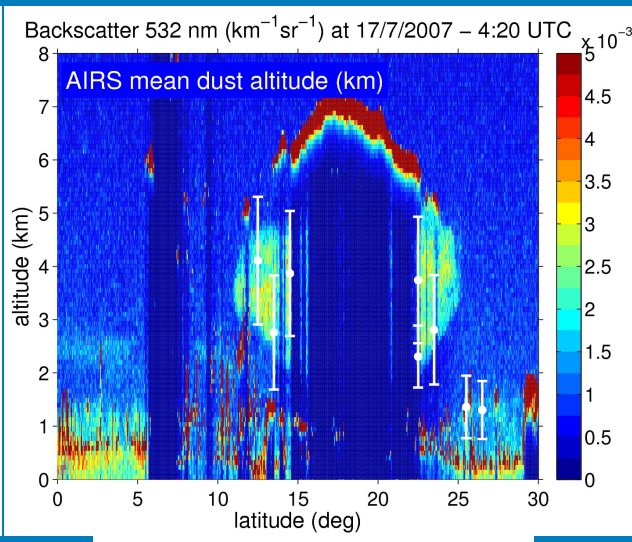


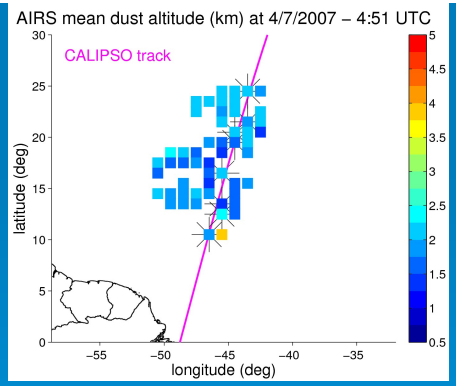


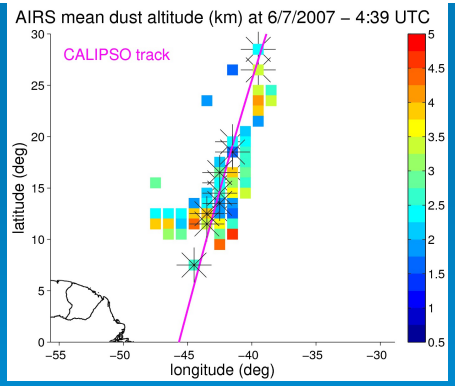
AIRS altitude comparison with CALIPSO

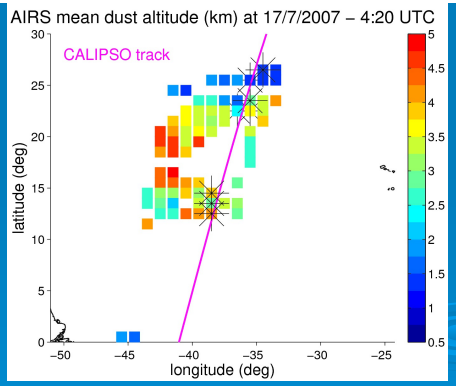








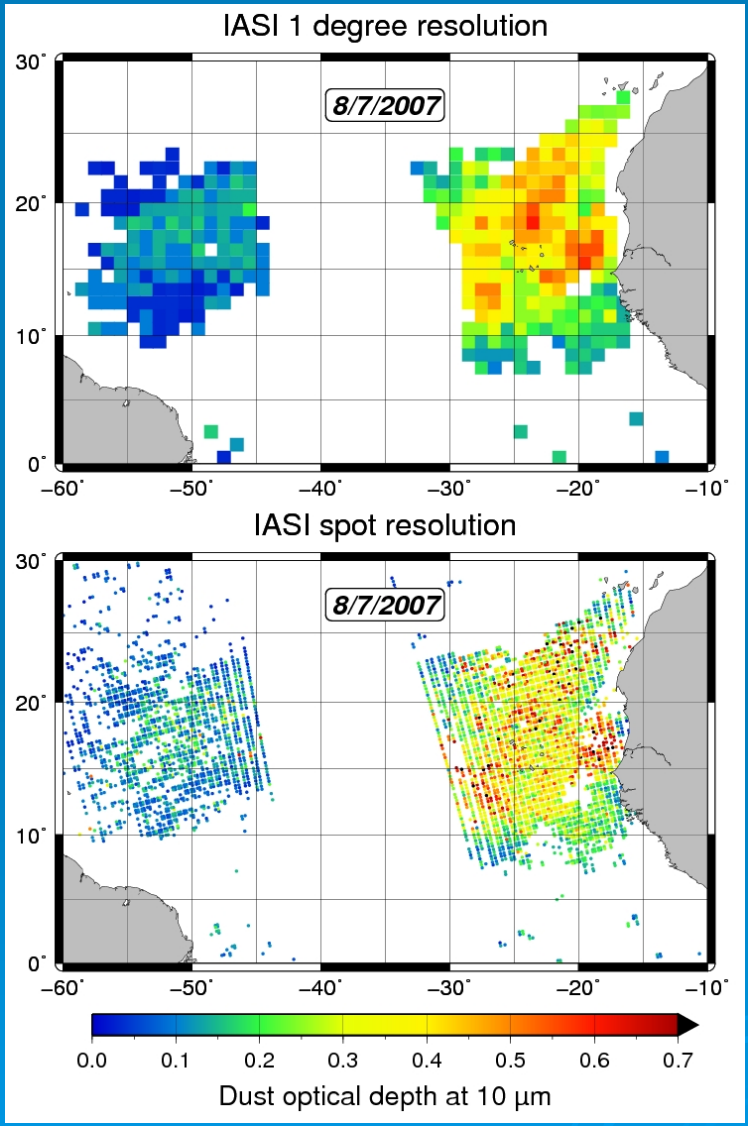


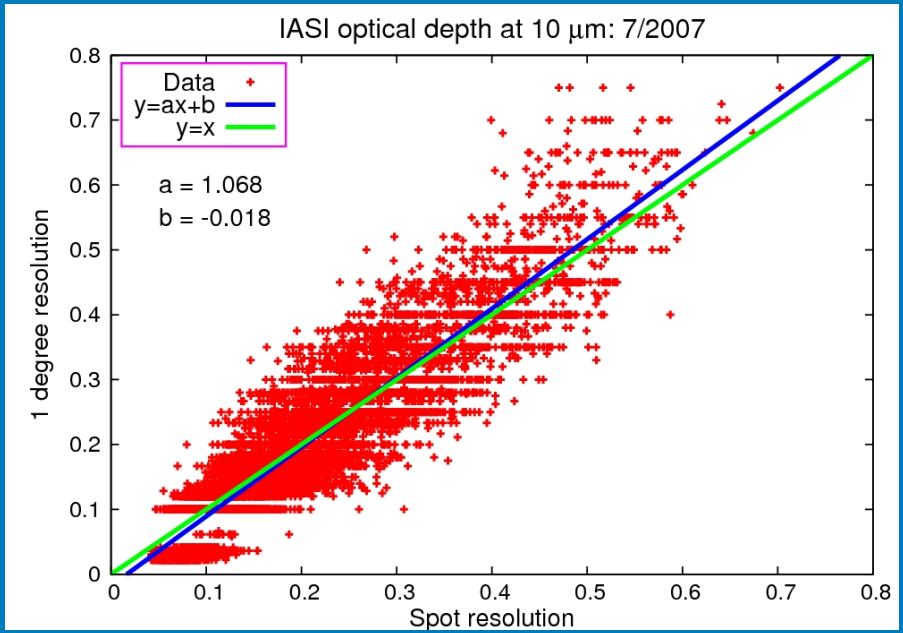


First results with **daily resolution** demonstrate relatively successful retrieval, although AIRS tends to underestimate the dust altitude, improvements in progress.

Comparison with IASI more complicated (due to different time).

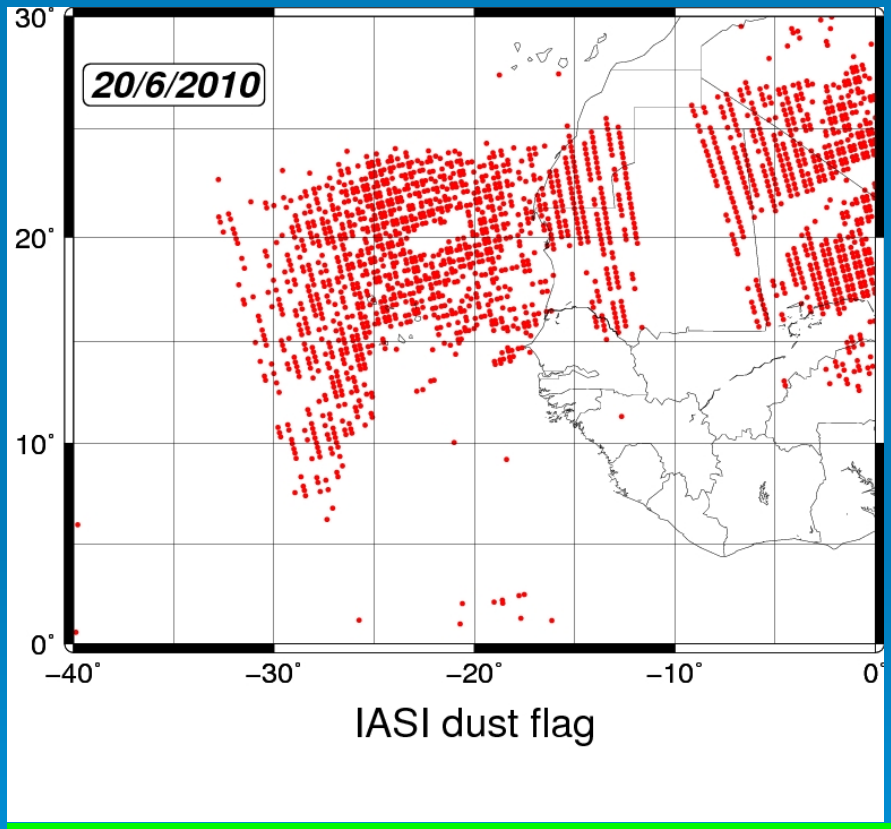
Achieving spatial resolution of 1 spot

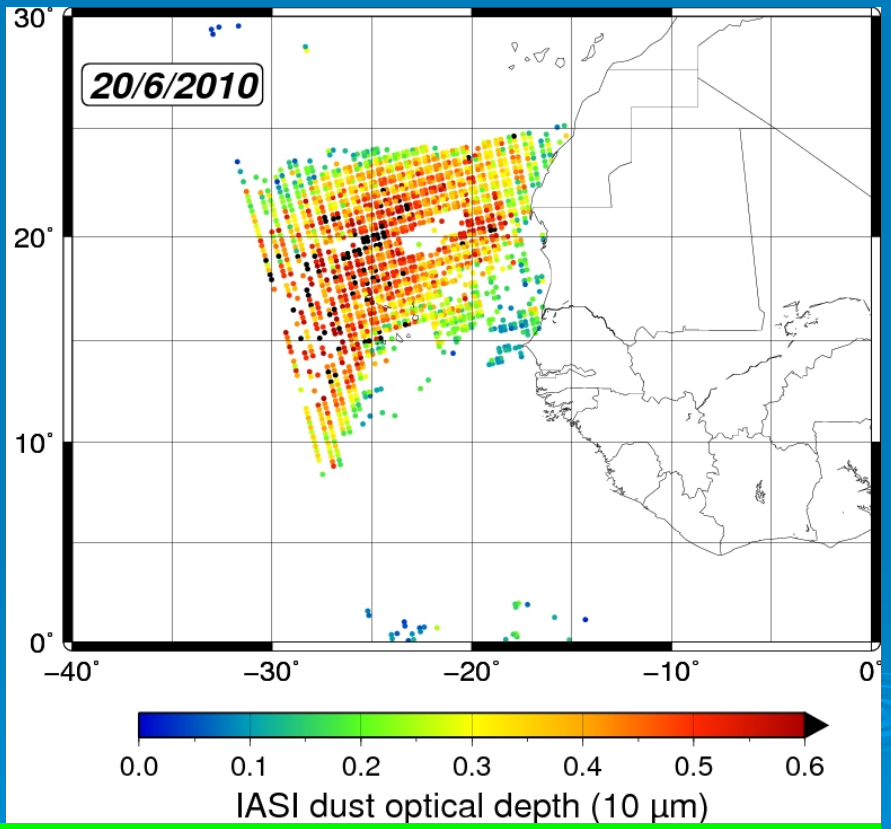




- Slight modification of the inversion method permits the optical depth retrieval with 1 spot spatial resolution.
- Comparison between 1 degree resolution and spot resolution for IASI during July 2007 demonstrates good correlation with coefficient ρ=0.92.

First step to the quantification of dust aerosols above deserts from IASI

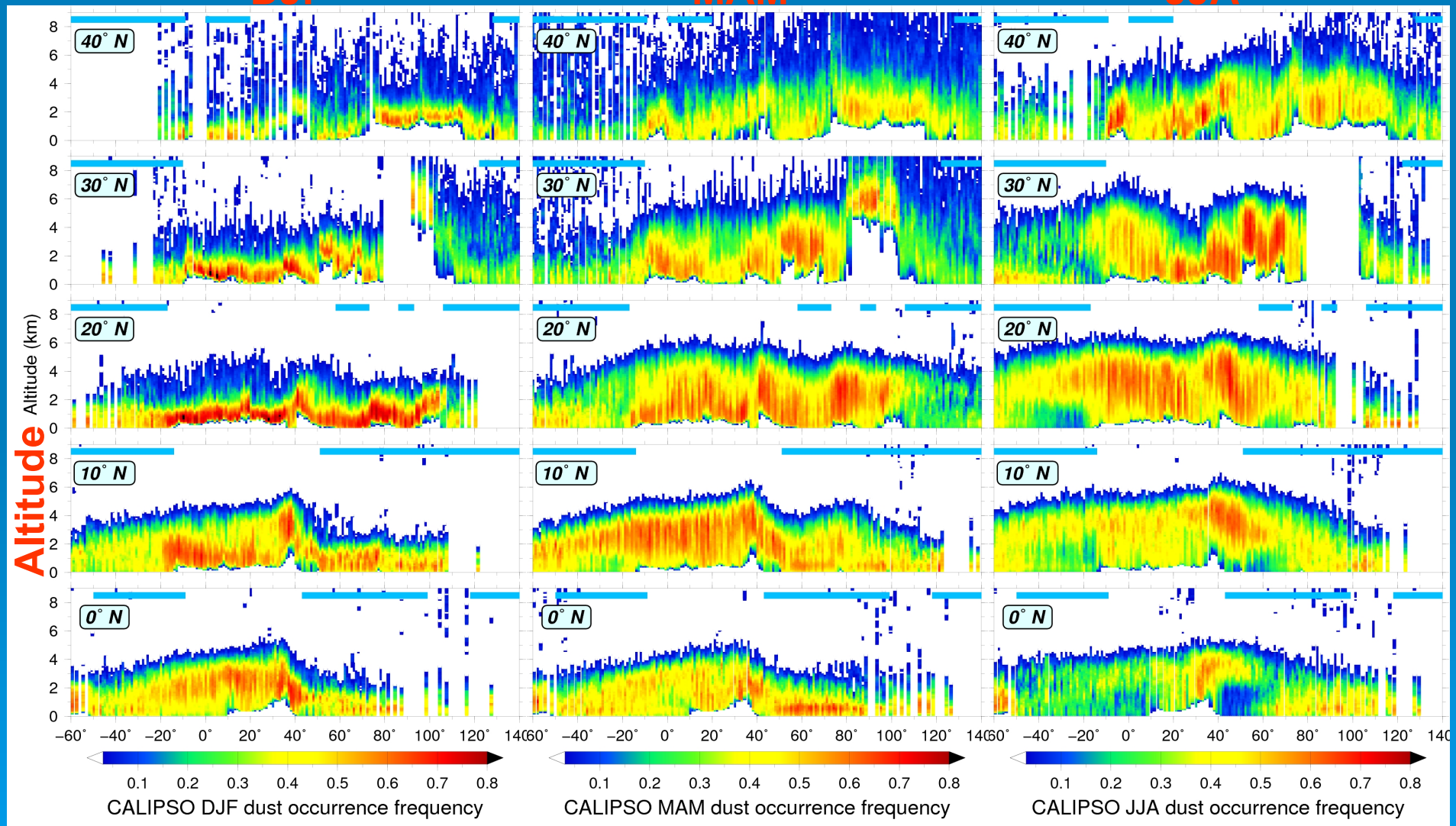




Example of dust detection (both above sea and desert) and its optical depth at 10 μm above sea.

Vertical distribution of dust aerosols from CALIPSO

Tsamalis et al., in preparation



Conclusions

- Dust **optical depth** and **mean altitude** from AIRS (1/2003 – now) and from IASI (7/2007 – now) with 1 degree – 1 month space-time resolution.
- Good comparison of IR dust characteristics with MODIS (optical depth) and CALIOP (altitude).
- Retrieval of coarse mode effective radius from IASI.
- Very encouraging first results of dust properties in the IR with the best possible resolution (1 day-1 spot) compare rather well with MODIS and CALIOP daily observations.
- First step towards the quantification of dust properties above deserts.
- First global dust altitude seasonal climatology with 1 degree resolution from CALIPSO.

Perspectives

- Further developments of the algorithm (modifying the inversion method, more dust aerosol models).
- Improvement and quantification of errors for daily and monthly products.
- Retrieving aerosol properties above continents and particularly above deserts (difficult to achieve at solar wavelengths) by using the IASI surface properties (emissivity and surface temperature from Capelle et al., submitted to JAMC).
- Retrieving aerosol properties during daytime.
- Retrieving other types of aerosols, e.g. biomass burning.

Thank you!

- CALIPSO data were obtained from ICARE Data and Services Center (http://www.icare.univ-lille1.fr).
- MODIS data were obtained through NASA's Giovanni, an online visualization and analysis tool, developed and maintained by the NASA GES DISC.
- This work has been supported in part by the European Community under the contract FP7/2007-2013 (MACC project).